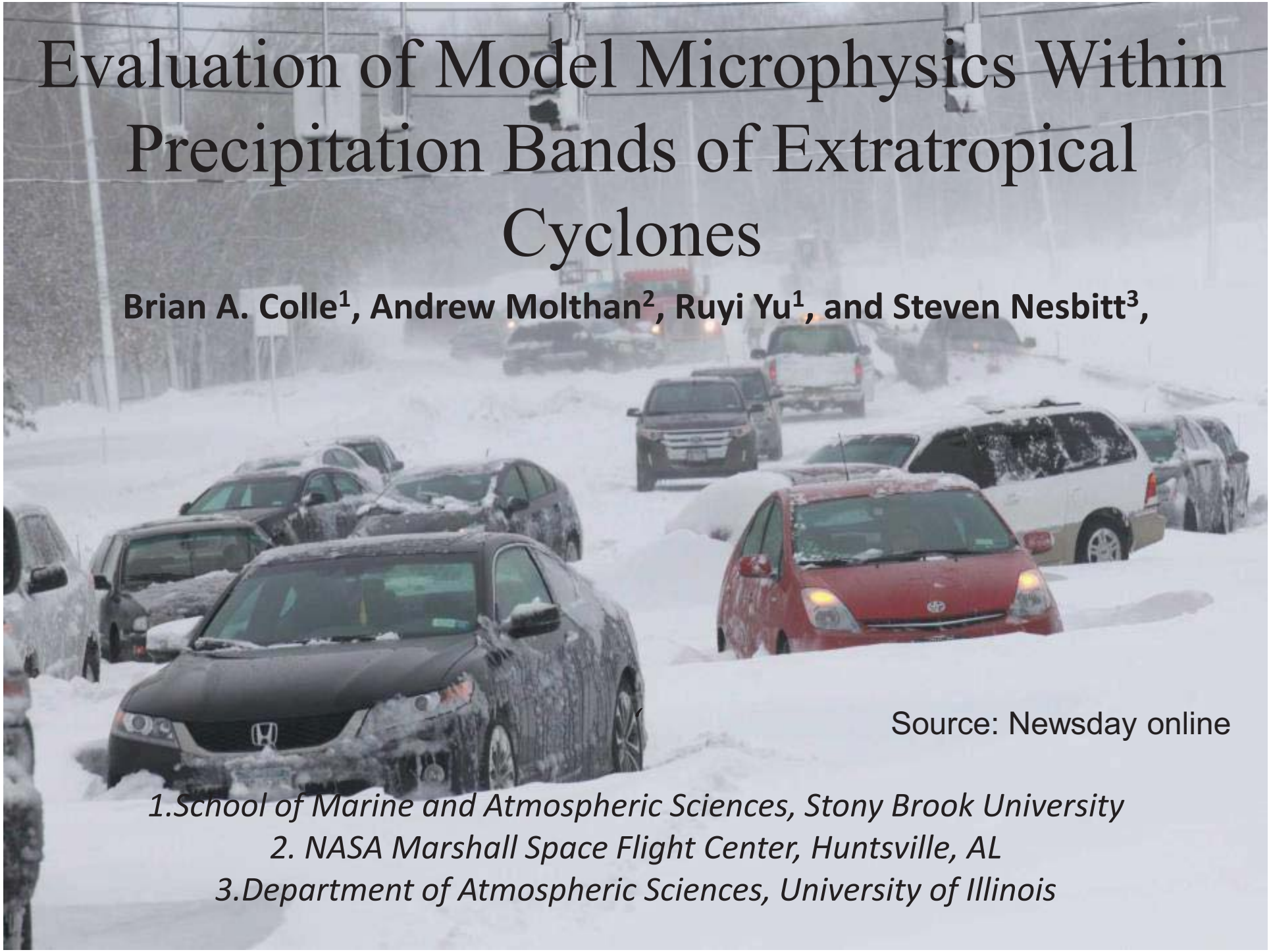
Evaluation of Model Microphysics Within Precipitation Bands of Extratropical Cyclones

Brian A. Colle[1], Andrew Molthan[2], Ruyi Yu[1], and Steven Nesbitt[3],



Source: Newsday online

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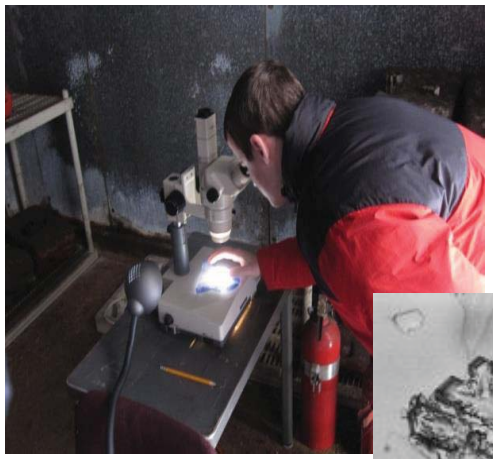
2. NASA Marshall Space Flight Center, Huntsville, AL
3.Department of Atmospheric Sciences, University of Illinois

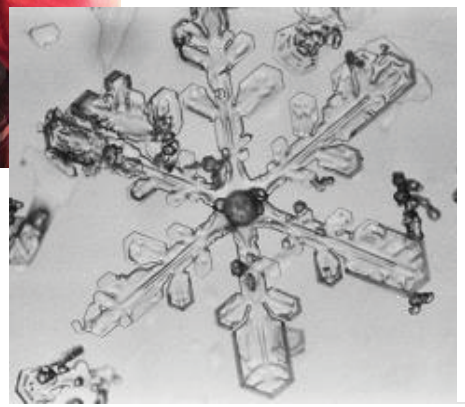
Motivation and Approach

• NASA Global Precipitation Measurement (GPM) Missions results in a number of new datasets to evaluate the performance of bulk microphysical parameterizations.

• It is hypothesized that many bulk microphysical differences in-cloud are related to how snow and rimed snow are parameterized.

• Approach: Utilize the Global Precipitation Measurement (GPM) Mission field studies (e.g., GCPEx 2012) to verify and improve parameterizations, as well as radar/microphysical obs of snowbands over Long Island,

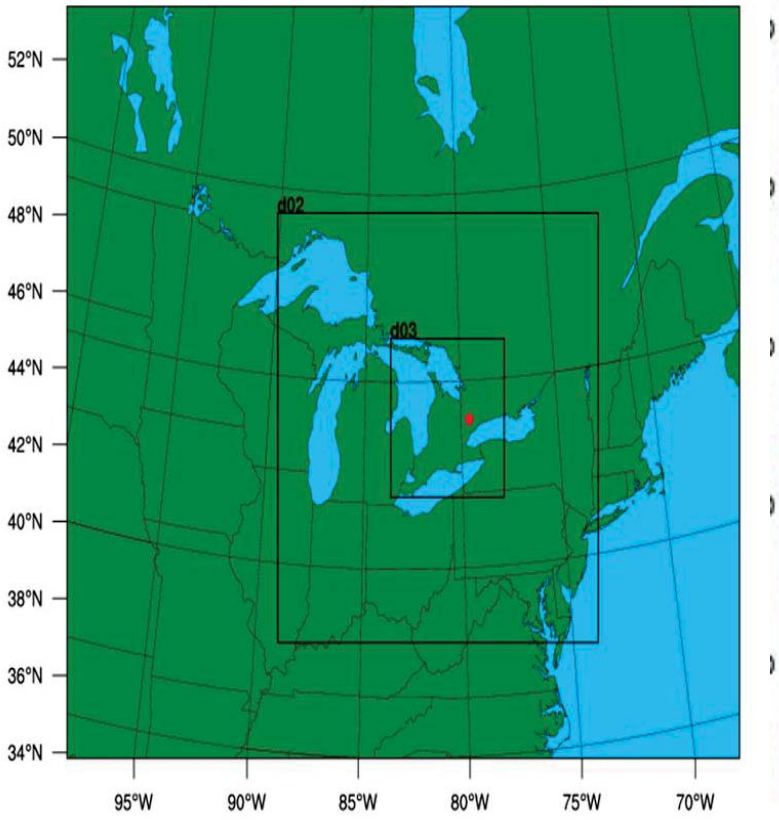


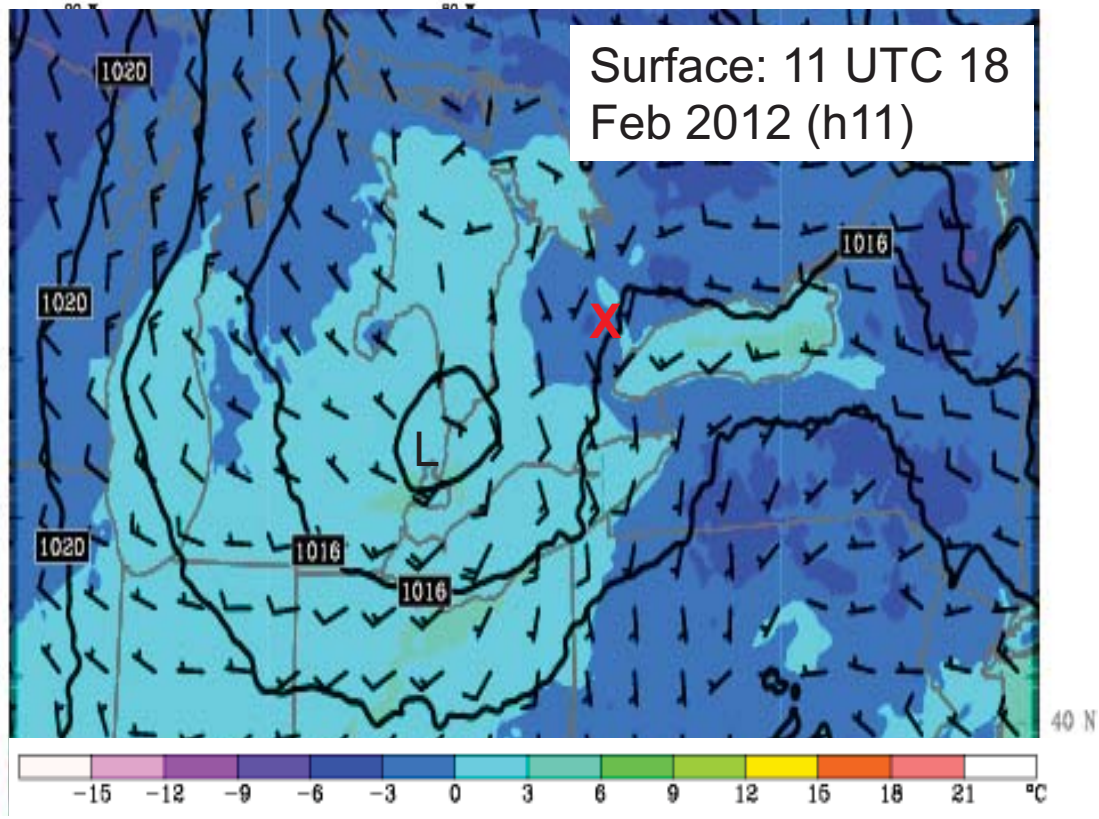


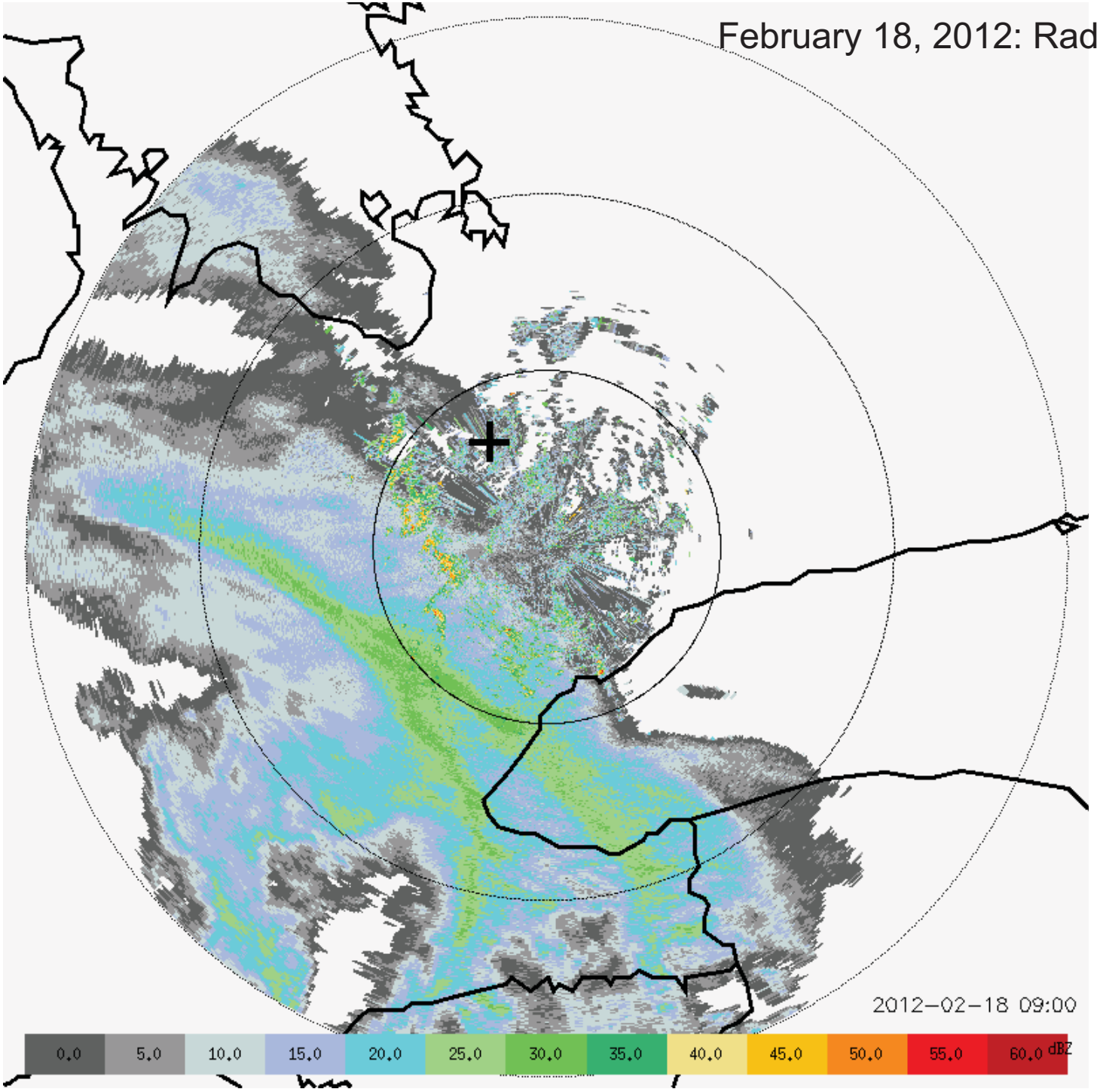
GCPEx GV measurements			Applicable Measured and/or Diagnosed Parameters															
Instruments		Measurable	Z	Z_{DFR}	R	PSD_{sfc}	PSD_{col}	PID	ρ_b	ρ_p	T	Q_v	Q_{soil}	CN, CCN	TW_c	CW	IW	ε/σ_{sfc}	T_B
Ground Radar and Profiler	C-band Dual-Pol	Z, Vr, W, ZDR, Φ_{DP}, ρ_{hv}	☒		☒	☒	☒	☒											
	D3R Ka/Ku Dual-Pol	Z, Vr, DFR, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	☒	☒	☒	☒	☒	☒											
	X-band profiling	Z, Vr, W	☒		☒			☒											
	MRR2 profiling	Z, Vr, W	☒		☒	☒	☒	☒											
	W-band profiling	Spectra (Z, Vr)	☒		☒	☒	☒	☒								☒			☒
	Dual freq. LIDAR	σ					☒												
Ground Gauge and Radiometer	2DVD/Parsivel/POSS	DSD, shape, fall spd	☒		☒	☒		☒											
	Pluvio2 SWE Gauges	SWE Rate			☒														
	TPS 3100 Hot Plate	SWE Rate, Wind, T			☒						☒								
	Soundings	P, T, RH, wind									☒	☒							
	ADMIRARI Radiometer, MRR	T_B 19, 37 Z 24 GHz	☒		☒											☒			
	EC TP3000 Radiometer	TB 23-59 GHz									☒	☒				☒			
	EC Ground-Staring Radiometer	TB 10-89 GHz															☒		☒
	EC Surface Met. Inst.	P,T,RH, wind									☒	☒							
Aircraft	APR2 (Ka/Ku Radar)	Z, Vr, DFR, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	☒	☒	☒		☒	☒										☒	
	CoSMIR (Radiometer)	T_B 37,89, 165.5,183 H/V															☒	☒	☒
	CPI/2D-C/CIP, HVPS	Precip. Image	☒		☒		☒	☒	☒	☒					☒		☒		
	CDP	Cloud Water/Spectra					☒									☒			
	Nevzorov	Total water							☒						☒	☒	☒		
	King Probe	Cloud water bulk														☒			
	Rosemount Icing Probe	Supercooled water														☒			
	Aircraft T/RH/Gust	Air T, RH, wind									☒	☒							

Global Precipitation Mission (GPM) Cold-season Precipitation Experiment (GCPEx 1/15/2012 - 2/29/2012) (UND Cessna Citation aircraft for microphysics and numerous group radar and surface obs)

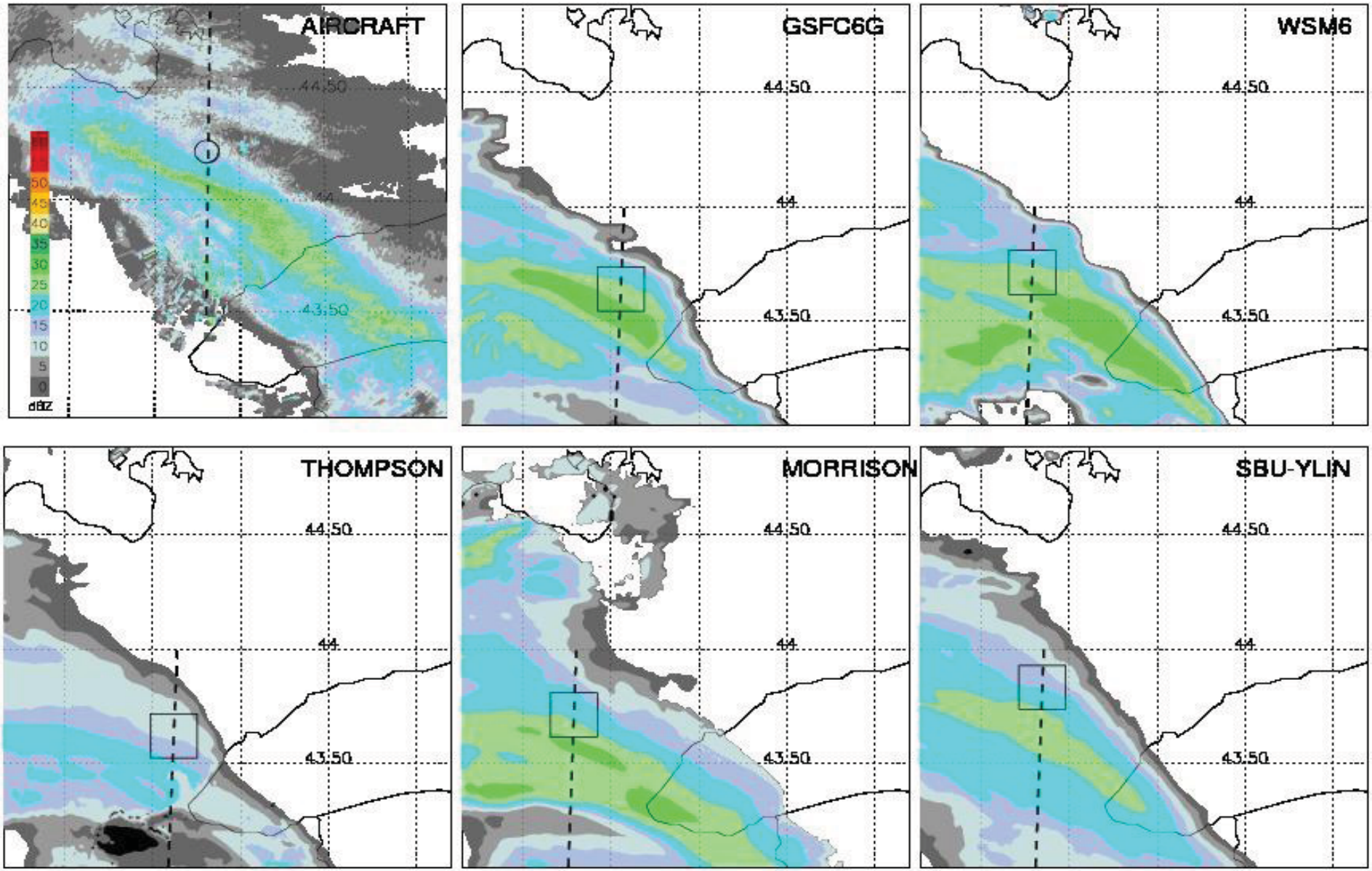
WRF run at 9, 3, and 1-km grid spacing using V3.5; YSU PBL, K-Fritsch on 9-km, and 6 different BMPs.



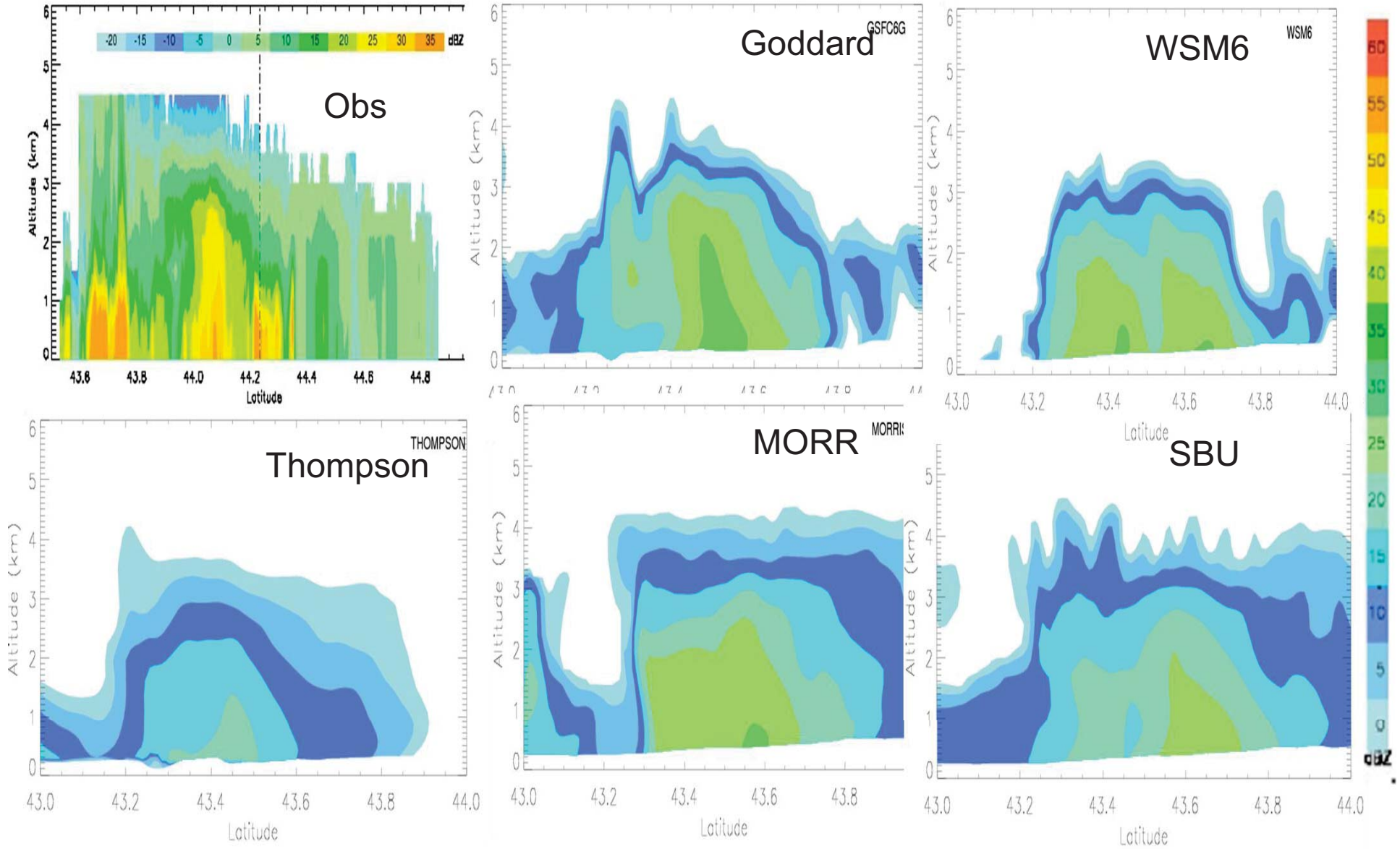



February 18, 2012: Radar Animatic
2012-02-18 09:00
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
dBZ

Warm Frontal Snowband at 1100 UTC 18 Feb 2012
(ground-based radar vs WRF Schemes)



Warm Frontal Snowband at 1100 UTC 18 Feb 2012
(Ground radar vs WRF Schemes)

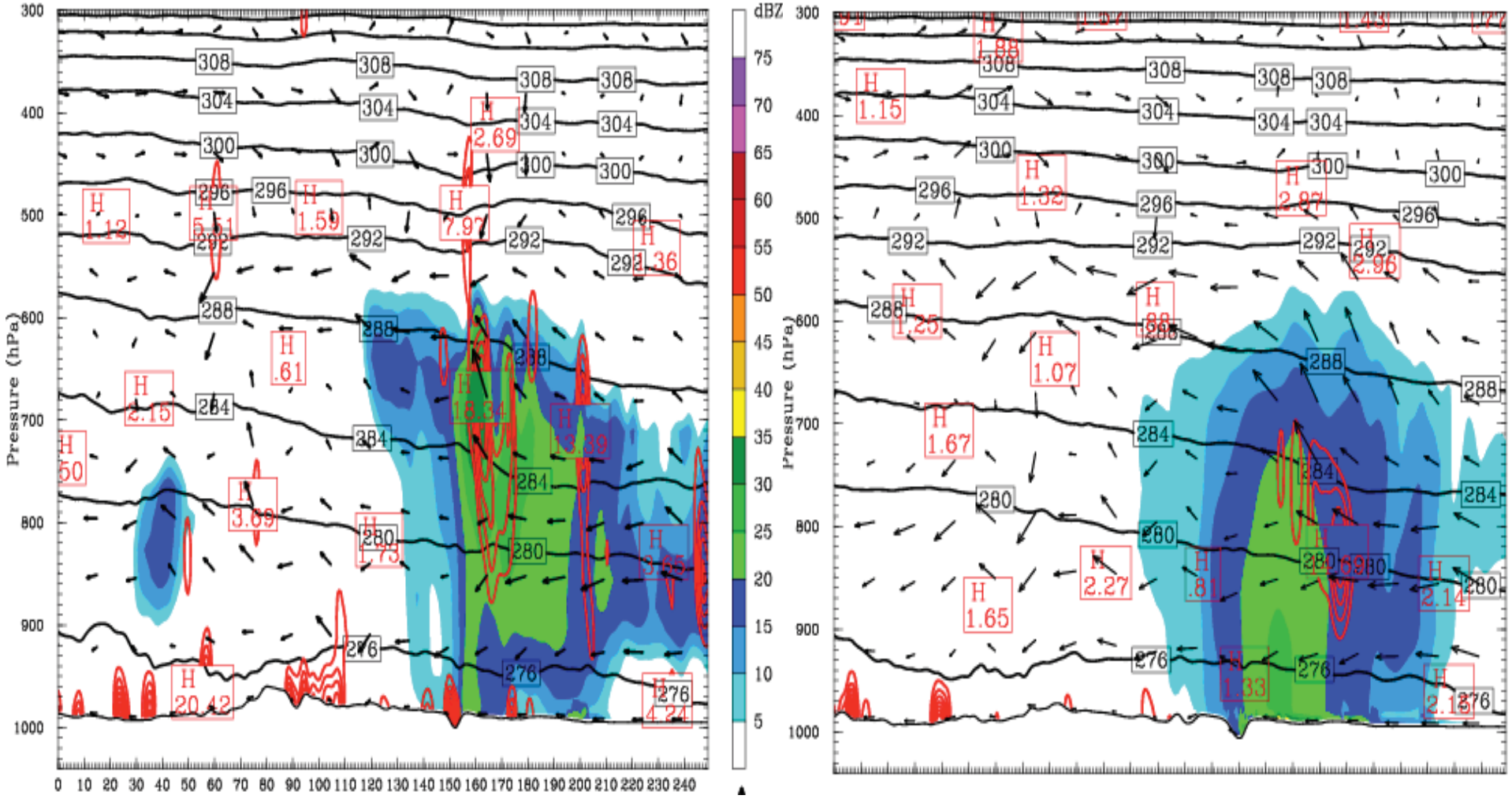


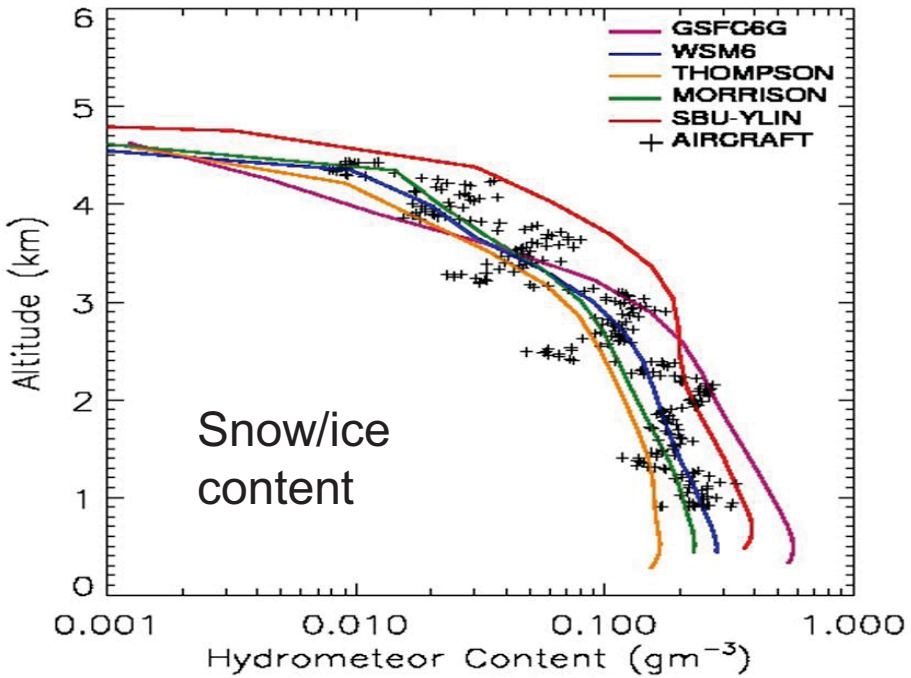
dBZ(shaded), potential temp, and Miller 2D frontogenesis

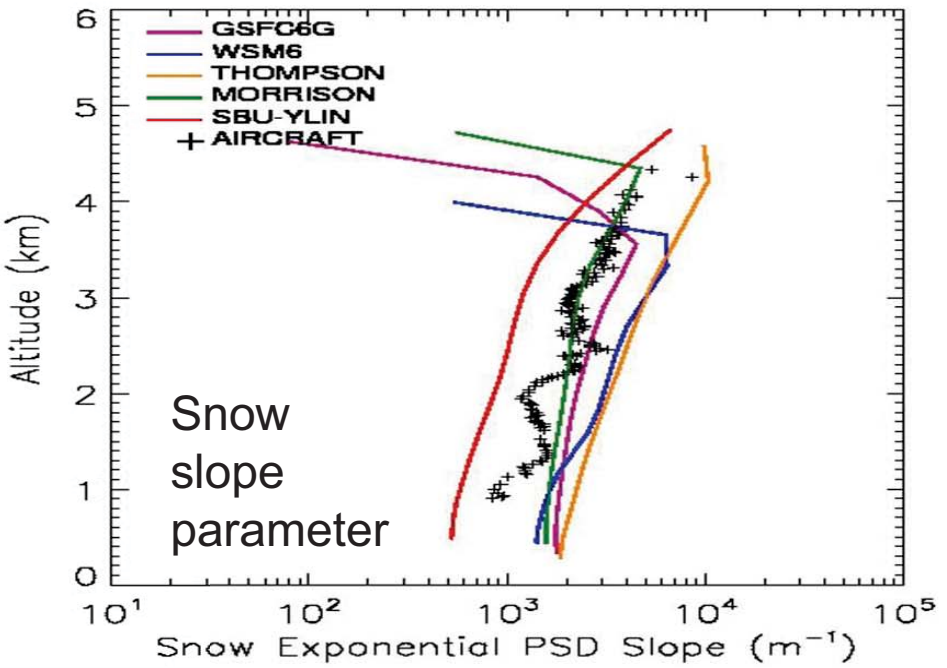
1100 UTC 18 Feb 2012

Goddard

Thompson







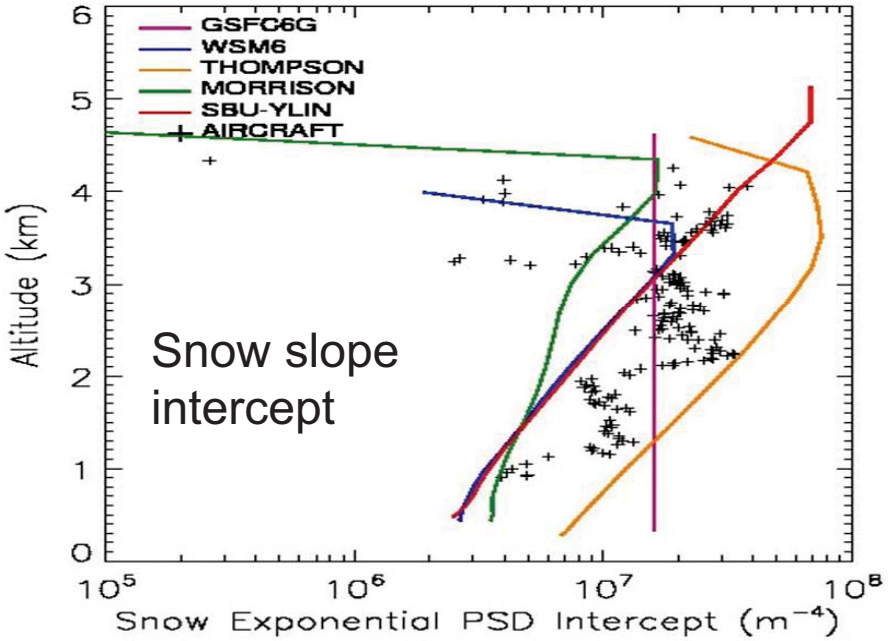
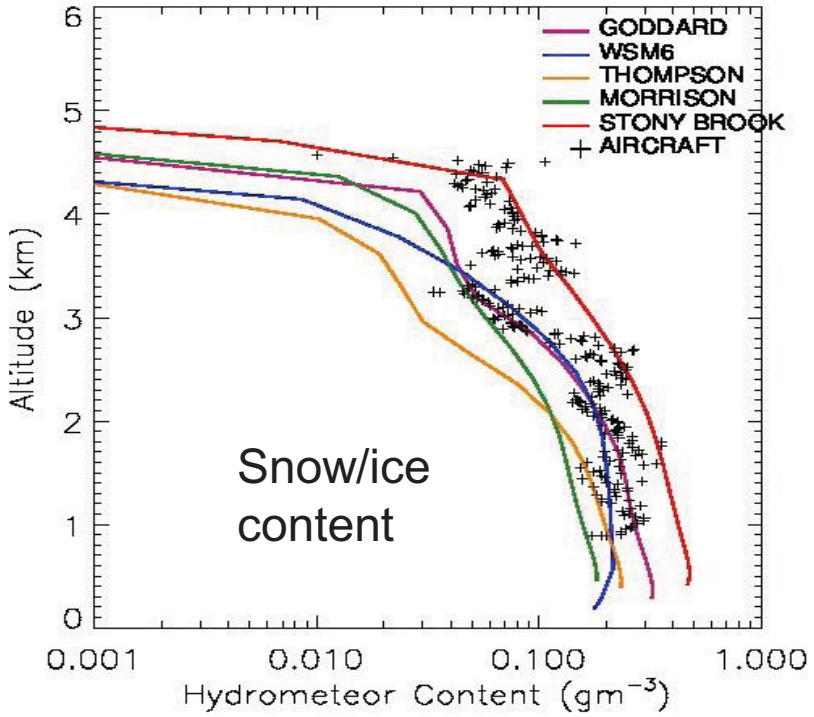
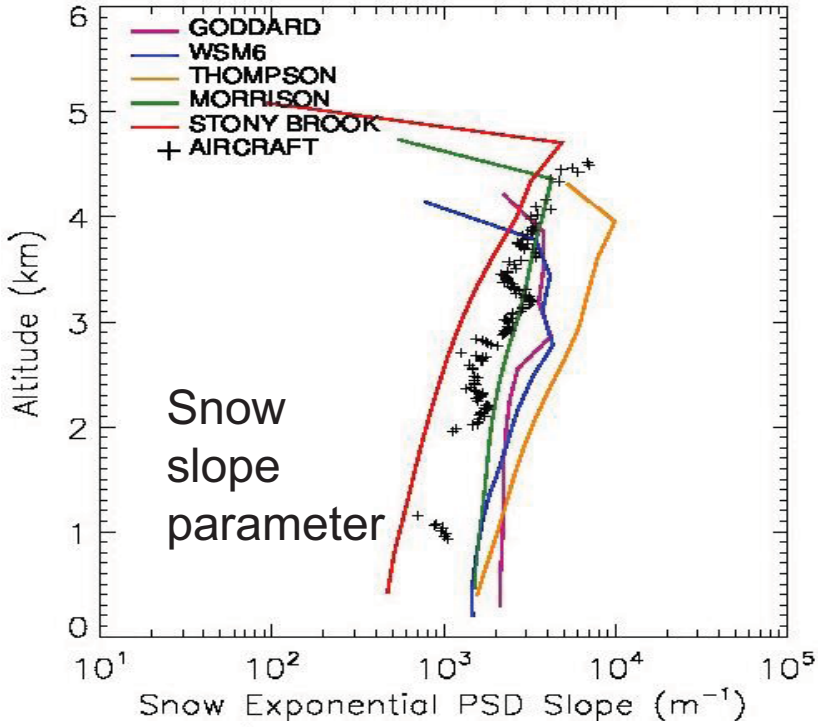
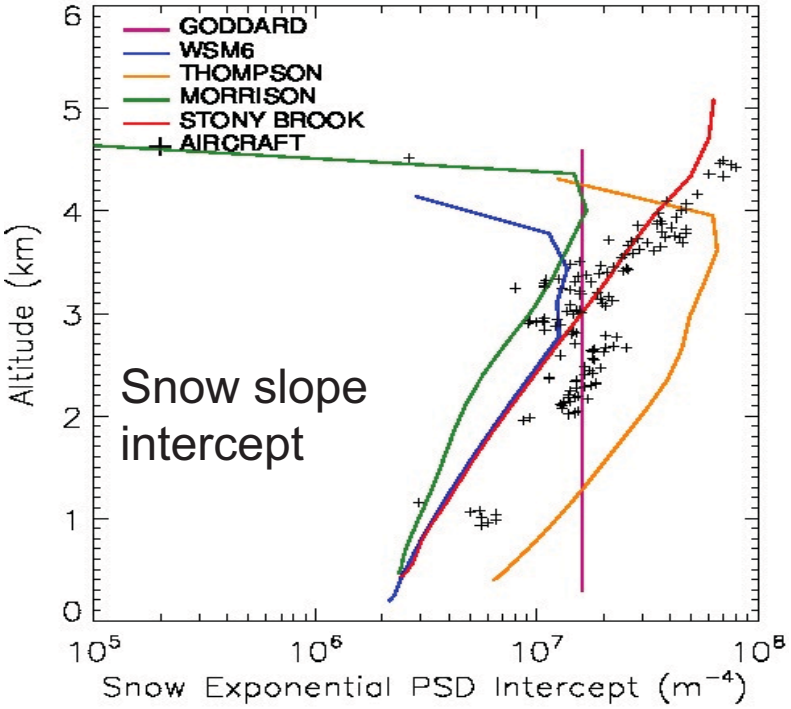


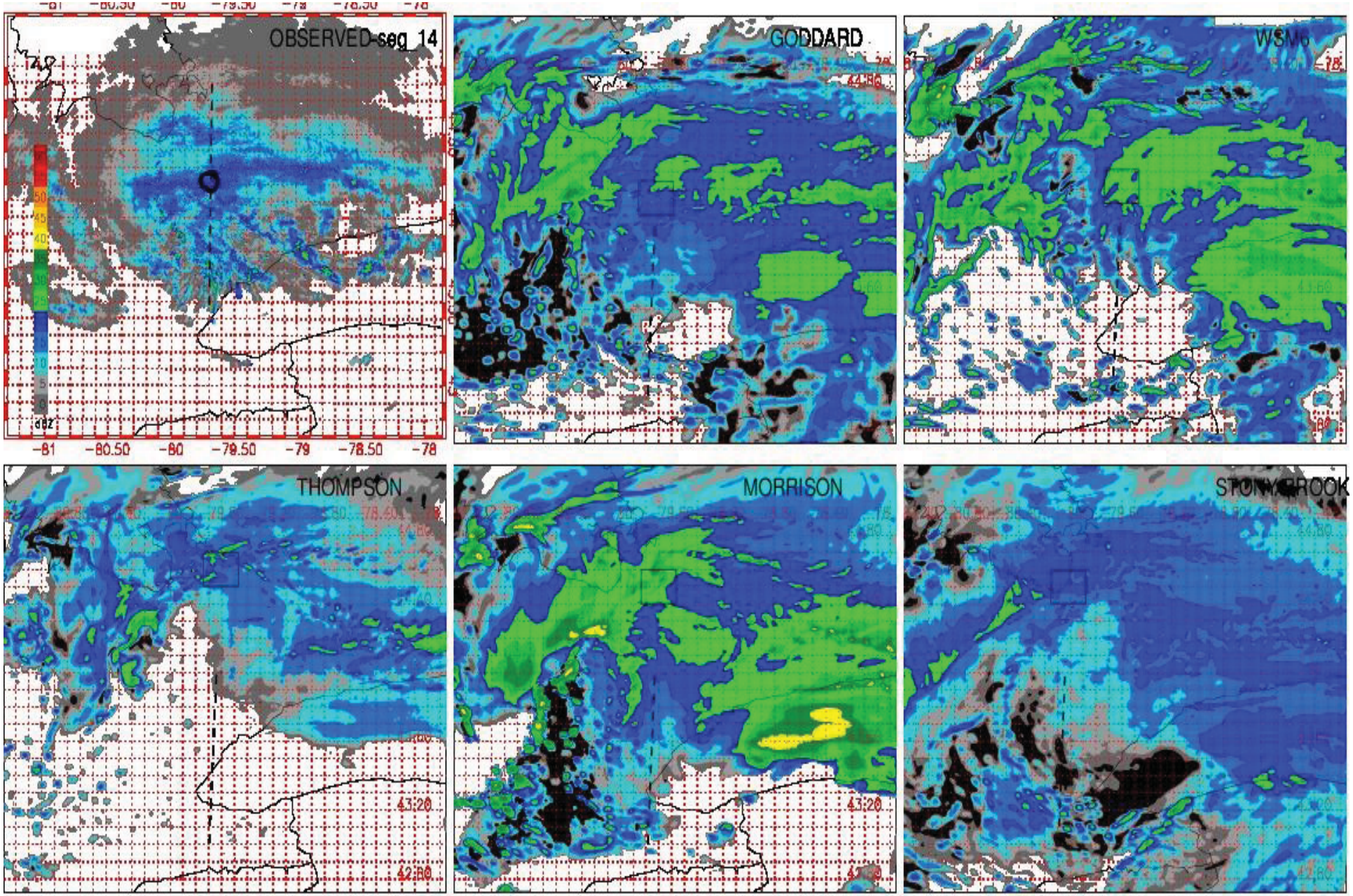
Figure 6. *Mean WRF profiles of ice water content, snow exponential PSD slope parameter, and intercept for the boxes in Fig. 2 in comparison to aircraft spiral.*

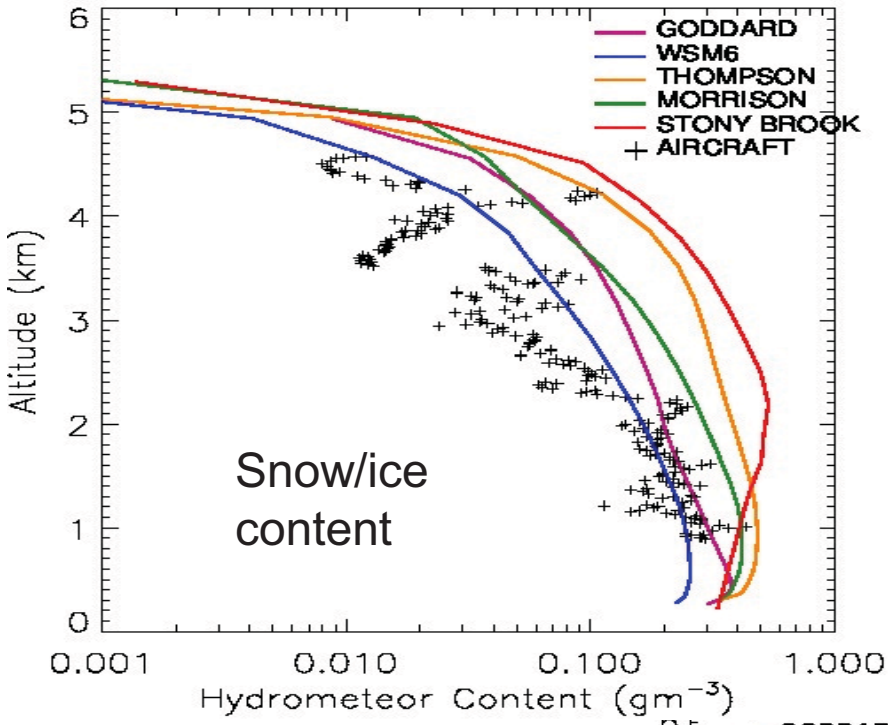


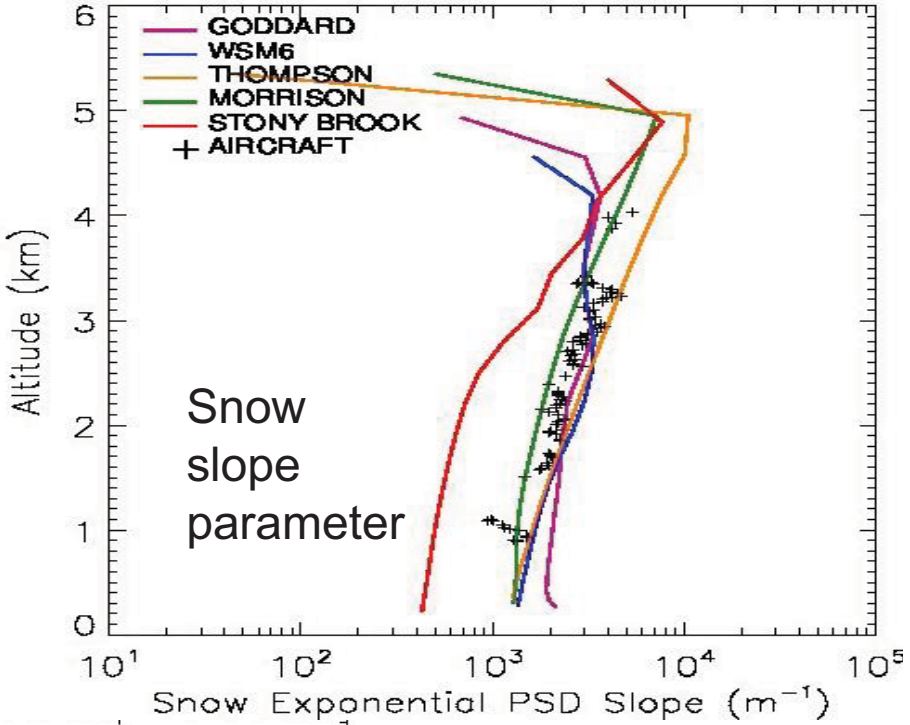


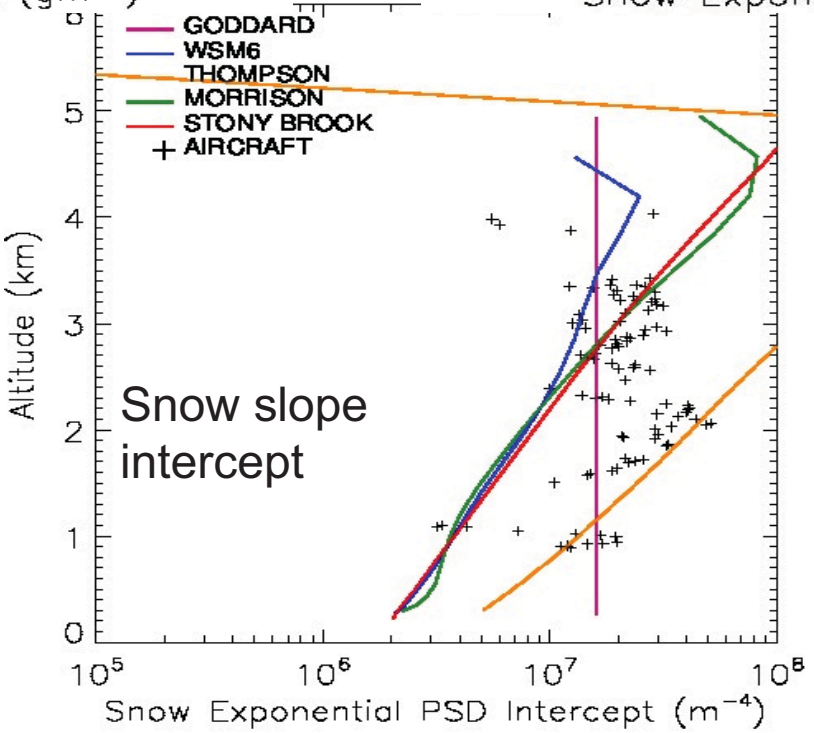
segment 7:
~1200 UTC
18 Feb 2012




OBSERVED-seg_14
GODDARD
WSM6
THOMPSON
MORRISON
STONY BROOK
dBZ
-81
-80.50
-80
-79.50
-79
-78.50
-78
43:20
42:R0

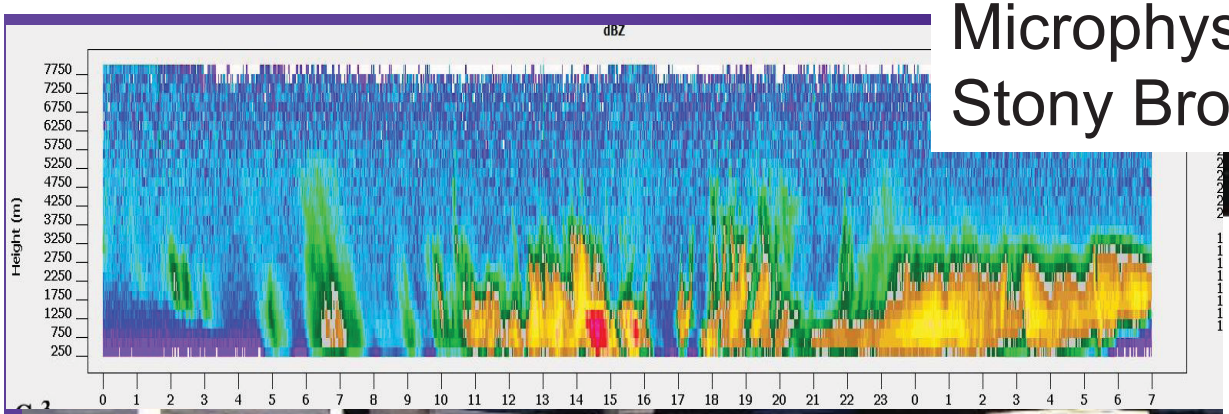






segment 14:
~1600 UTC
18 Feb 2012

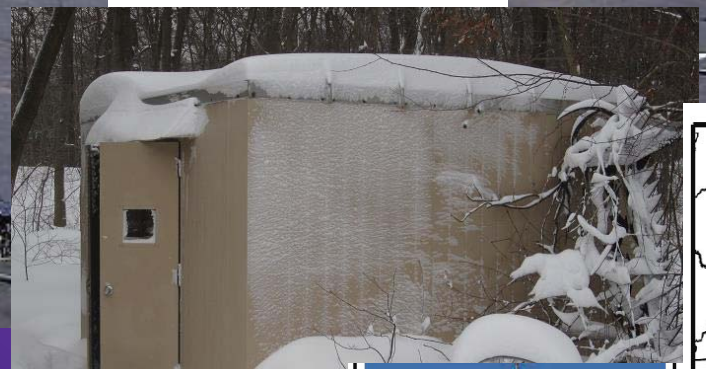
Microphysical Observations at Stony Brook, NY

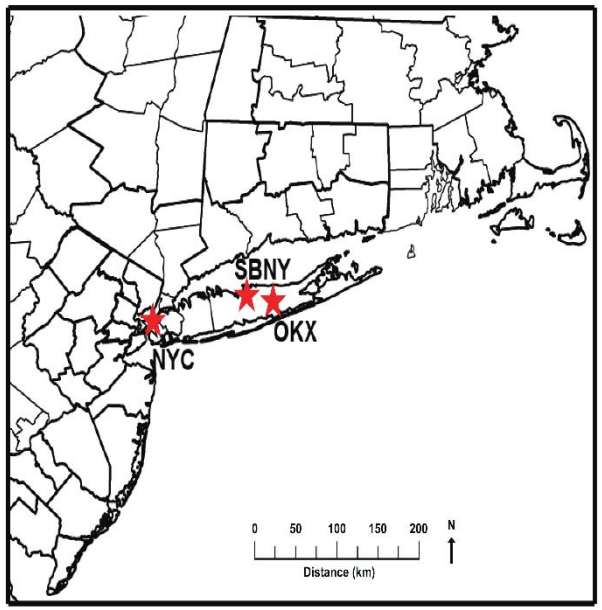


Particle Size and Velocity (PARSIVEL) disdrometer

MRR vertically-pointing radar (24 GHz)

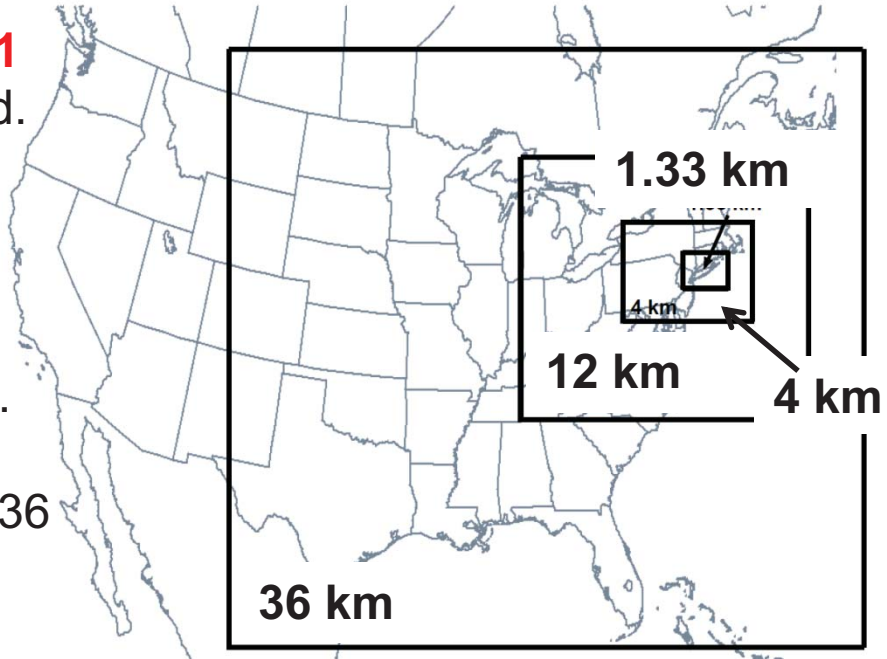
precip gauge



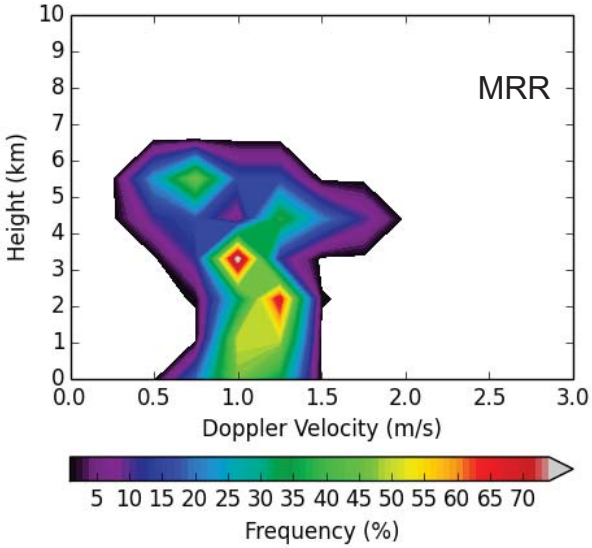


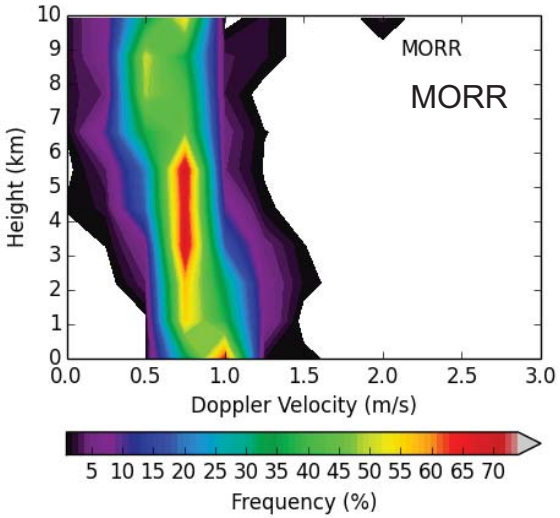
WRF V3.4 Simulations

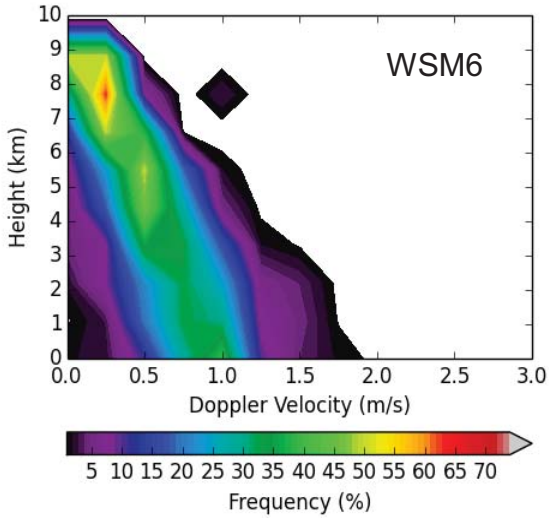
- 20091219_20, **20100108, 20100128 20100216, 20100226, 20110107, 20110221 20120121, and 20120211** events simulated.

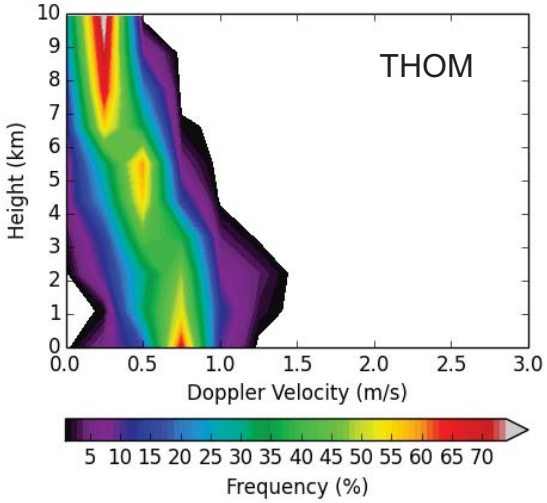


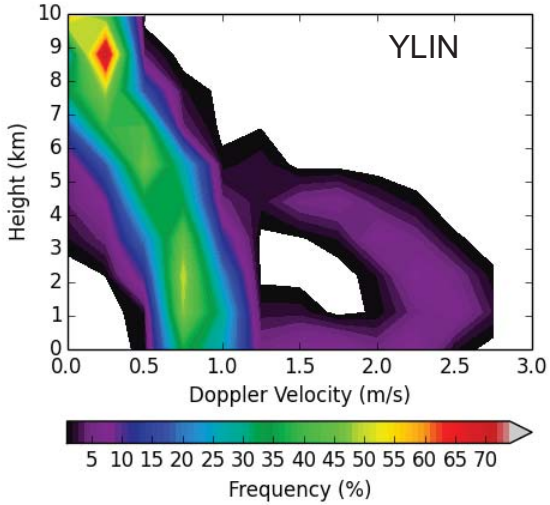
- 12-km NAM and 0.5° GFS used for initial and boundary conditions.
- 1.33-km grid spacing with 39 vertical levels.
- Betts-Miller-Janjic cumulus scheme on the 36 and 12-km domains.
- YSU Planetary Boundary Layer scheme and Unified Noah Land Surface Physics.
- Microphysics schemes: WRF Single Moment 6-class Microphysics, Thompson, Morrison Double Moment, and Stony Brook. All verification on the 1.33 km domain.
- SBNY was used as the verification point for all simulations except for 20091219_20 due to the snow band simulated west of observed location. A representative point for SBNY was chosen in these simulations.
- All simulations given at least six hours of spin-up time before any verification, except 20110107 (~4 hours of spin-up).





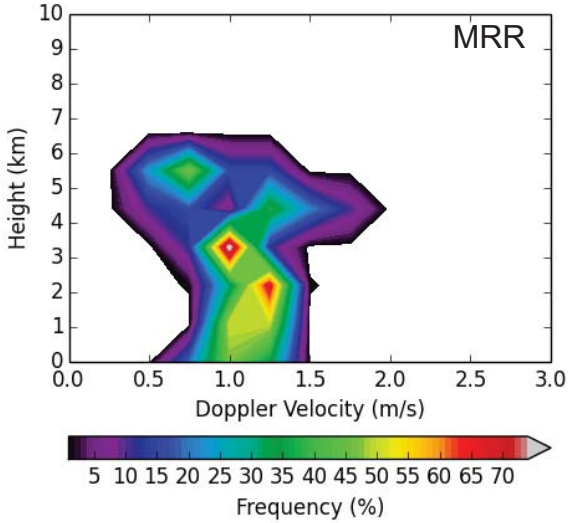






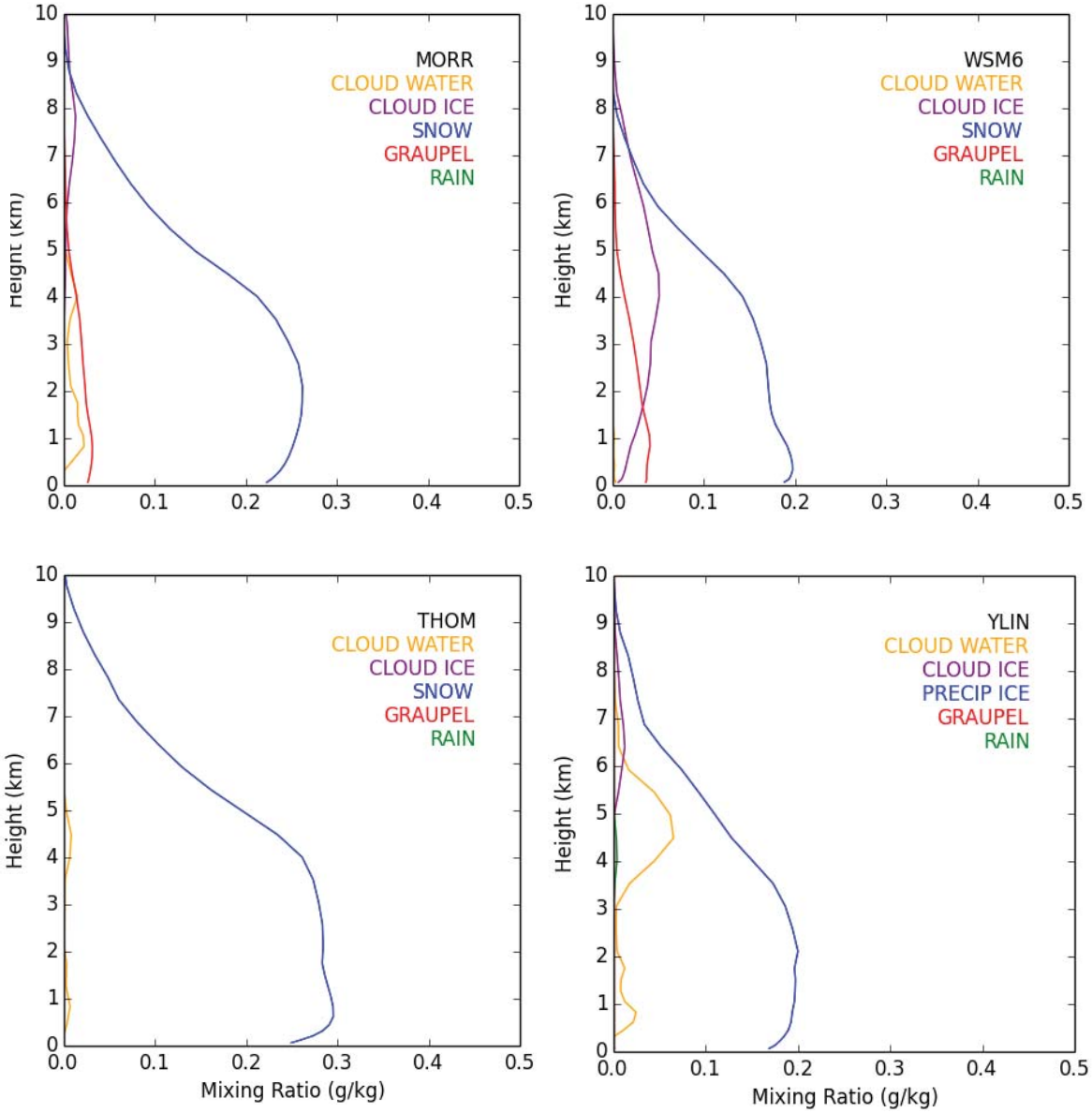
Light Riming (LR) Cases:

Vertical Doppler Velocities at SBNY



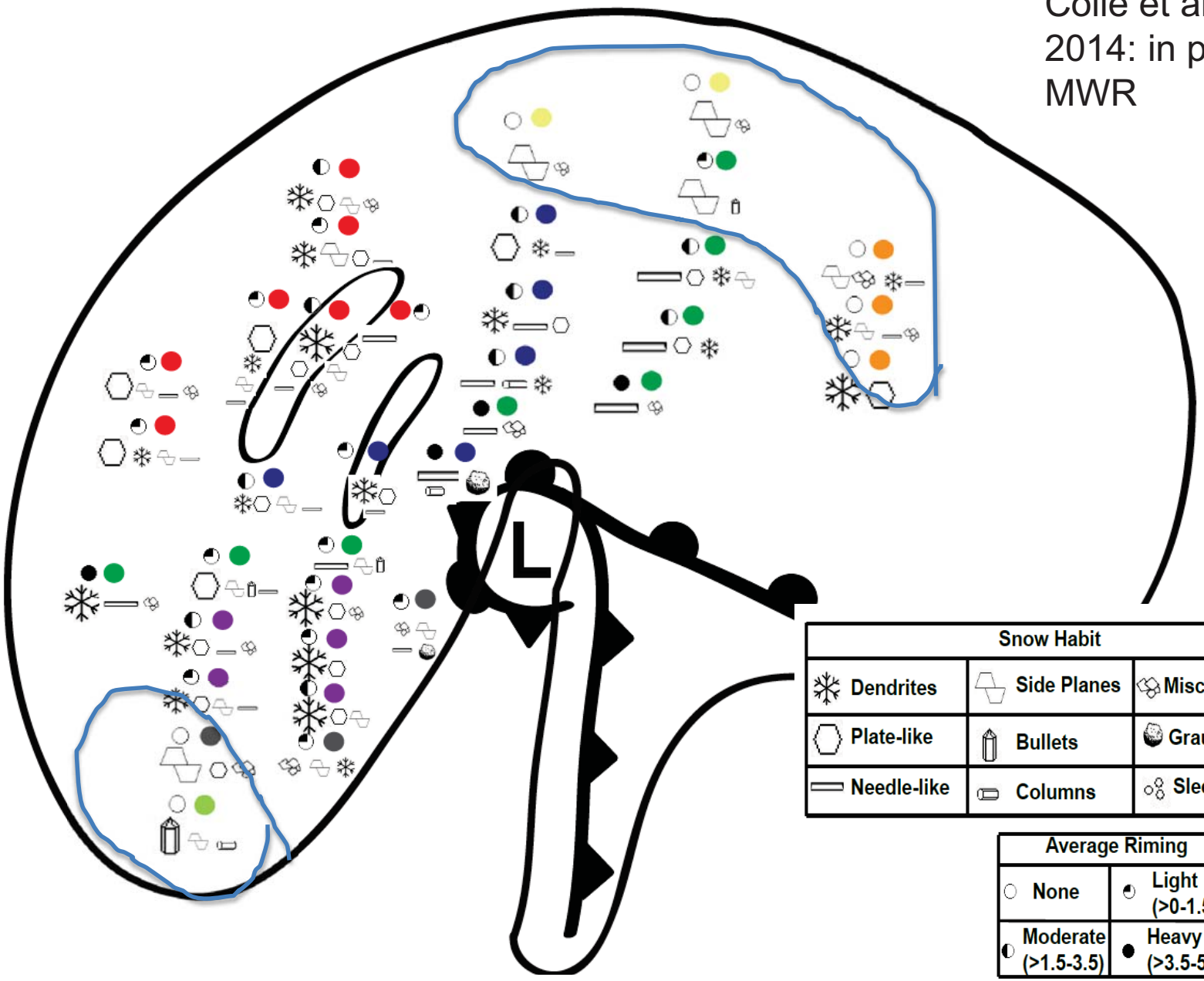
Light Riming (LR) Cases:

Mixing Ratio Profiles



Ice Habit, and Riming Evolution in Extratropical Cyclone Comma Head Occluded Stage

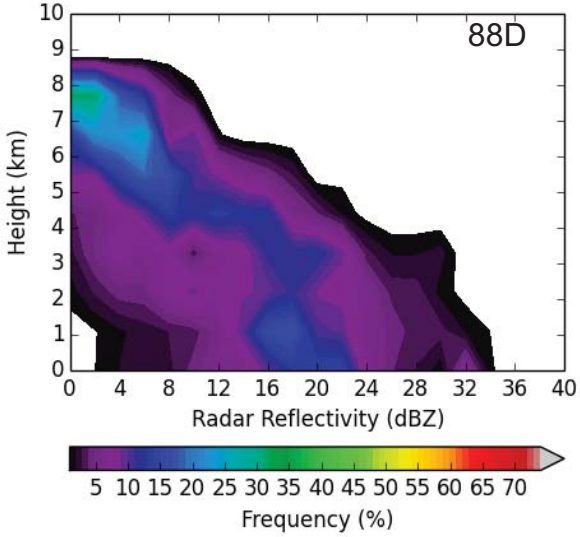
Colle et al.
2014: in press
MWR

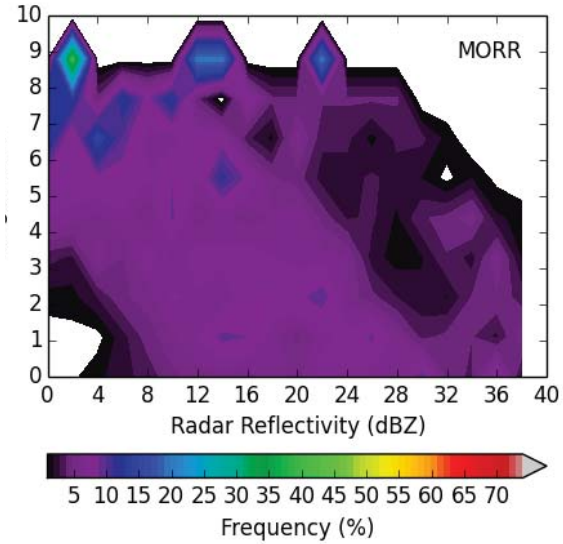


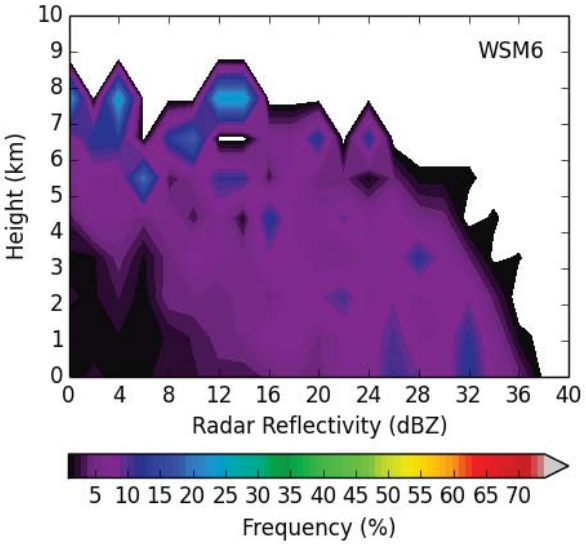
20091219-20
20100103-04
20100210-11
20100216
20100226
20100303
20100305
20110112

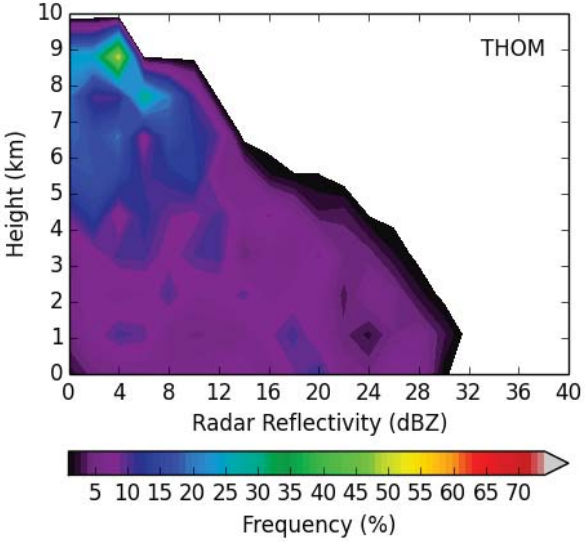
Snow Habit			Icon Size
Dendrites	Side Planes	Miscellaneous	>10-29%
Plate-like	Bullets	Graupel	>30-49%
Needle-like	Columns	Sleet	>=50%

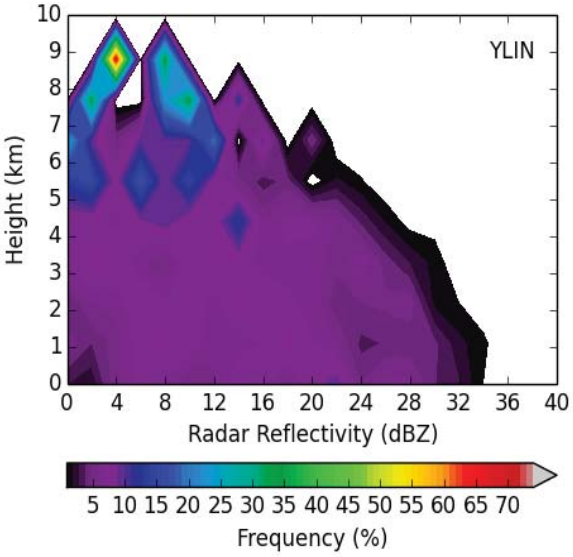
Average Riming	
None	Light (>0-1.5)
Moderate (>1.5-3.5)	Heavy (>3.5-5)







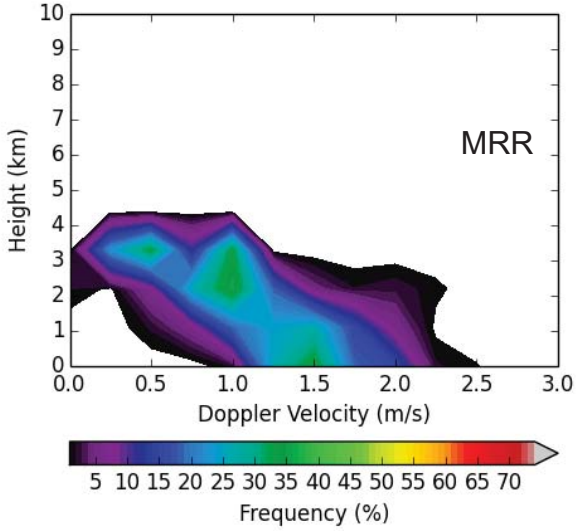


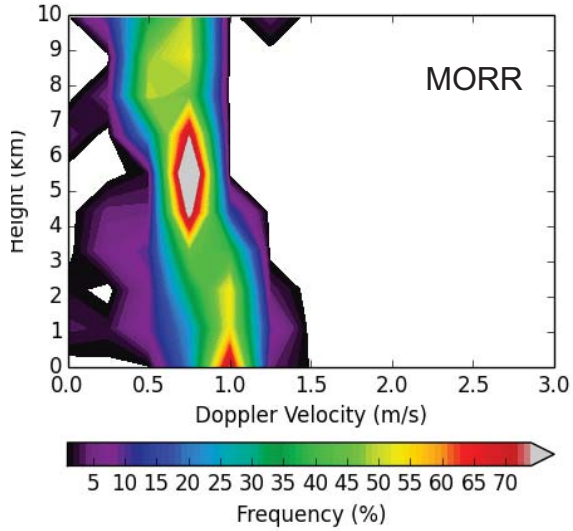


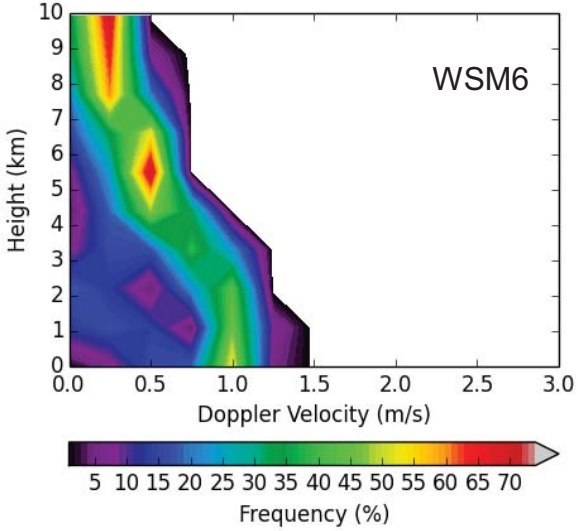
Light Riming (LR) Cases:

Reflectivity (dBZ) CFADs at SBNY

Heavy Riming (HR) Cases

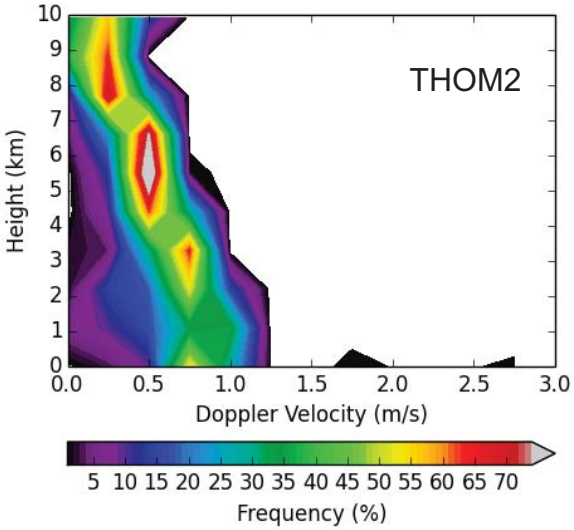


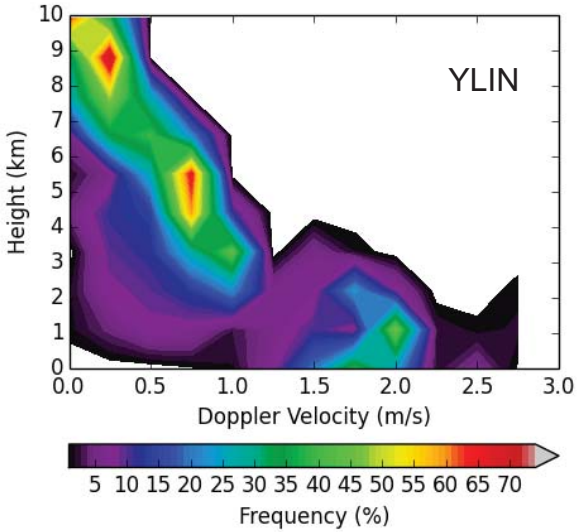


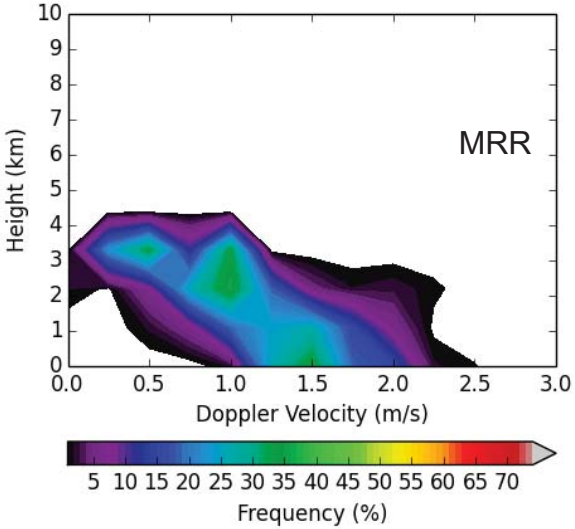


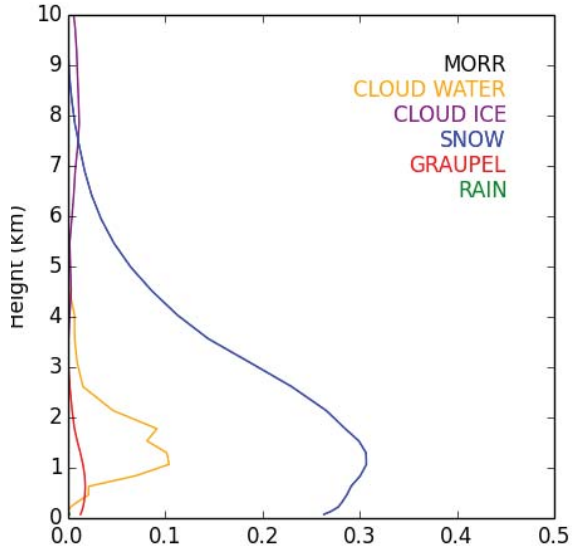
Heavy Riming (HR) Cases:

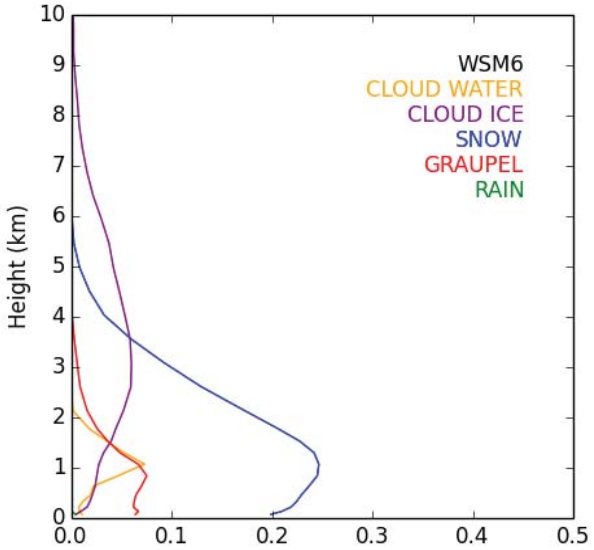
Vertical Doppler Velocities at SBNY

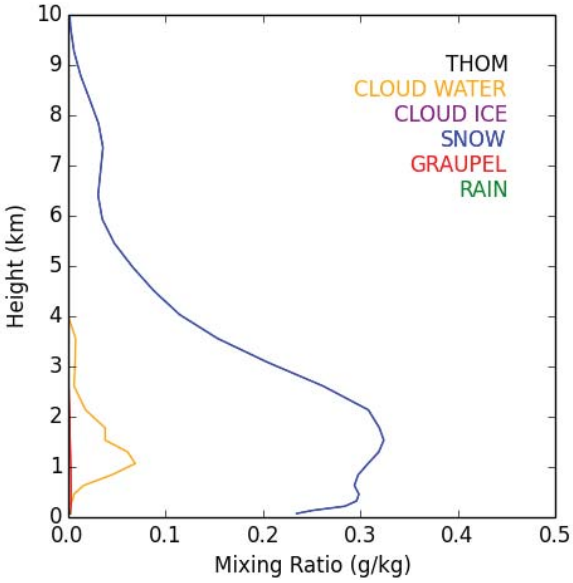


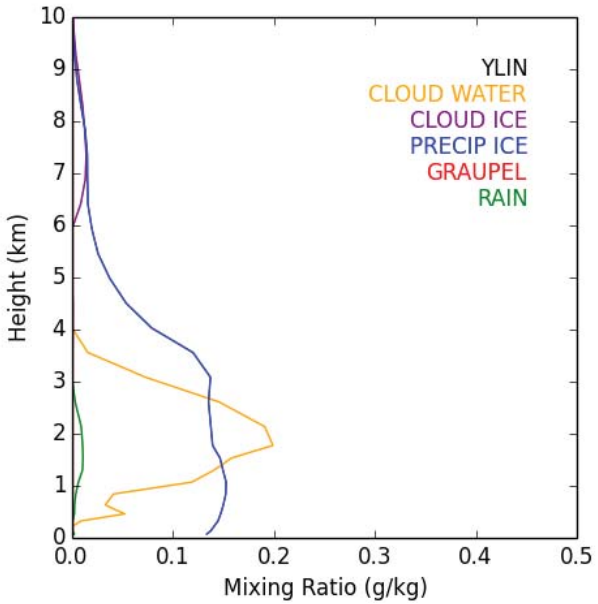












Heavy Riming (HR) Cases:

Mixing Ratio Profiles

Conclusions

- All bulk microphysical schemes produced a realistic warm frontal precipitation band (and hydrometeor contents) during the 18 Feb 2012 GCPEx case, although Thompson is somewhat too weak.
- Morrison (double moment) had the best snow slope parameter (gamma), but not the best slope intercept. Intercepts a function of temperature were best (SBU and WSM6) and constant intercept (Goddard) worst.
- For a larger number of winter storms, there is less microphysical variations for relatively light riming events. All schemes underpredicted fallspeeds for light riming, likely related to fast-falling cold type crystals. Schemes using non-spherical assumptions (Thom and SBU) best for reflectivity profiles.
- All schemes underpredict the average snow fallspeed for heavily rimed events, suggesting too little riming.

Microphysical Cross sections at 1100 UTC 18 Feb 2012